



ASSESSING SOIL ERODABILITY FACTOR FOR RUSLE2 IN BAHLUIEȚ CATCHMENT, EASTERN ROMANIA

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Abstract

In Romania, there is a lack of methodology for soil erosion estimation, in the sense that although a soil loss estimation equation similar with USLE is used, the factor estimation is not comprehensively covered. That is why we have turned to RUSLE2 methodology to compute soil erodability factor (K) for Bahluiet catchment (Eastern Romania). We have used a soil profile and soil unit legacy database for estimating K values from granulometry sand, silt and clay values. We tested the two equations proposed by the RUSLE2 methodology, but we have chosen to use the values from only one of them, because for the other the estimated value were incomprehensibly high. For comparison, we have used also an estimation made by the EUROSOIL JRC and based on the same equation for which the estimation failed. The majority of the soils from the study area are from the clay loam, sandy clay loam, sandy loam and loamy texture classes. The mean K factor value is 0.0181, corresponding to soils with low erodability. The K values stretch from 0.01 to 0.03, the majority of the soils in the study area having K values in the range between 0.01 and 0.022. We observed a spatial pattern in K values distribution which is explained by the lithology of the study area, the central, southern and eastern areas having bigger soil erodability, because of the loamy texture, while western areas have a sandy loam texture, which give lower soil erodability values. Our result is lower than the estimation of EUROSOIL JRC modelling, which for our study area has a mean of 0.043, and the majority of values falling in the 0.026-0.054 range. Our opinion is that these values are too big, since the texture of the soils is clayey to sandy loam. This conclusion seems to be sustained also by the soil erosion values and sediment yields obtained using our estimated K values, which are consistent with the soil losses and sediment yields reported in the study area, conclusion which cannot be drawn for the estimation of EUROSOIL JRC data (which will give overestimated soil erosion and sediment yield values).

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Keywords: RUSLE2, K factor, Bahluiet Catchment, soil erodability, Eastern Romania

1. INTRODUCTION

RUSLE model is the most used statistical model for assessing soil erosion (Kinnell, 2010), being derived from USLE (Wischmeier and Smith, 1965; Renard et al., 1997). Despite this, is well known that in general USLE and RUSLE under evaluate real values of soil erosion (Römkens et al.,

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1988; Warren et al., 2005), and can also fail to predict, mainly because of rainfall factor estimation problems (Kinnell, 2010). If the rainfall-runoff factor is reasonably estimated, USLE class models can easily outperform rainfall-runoff or physically based soil erosion models (Kinnell, 2010).

For the problem of under evaluation of soil loss, several methods were used for fixing, based mainly on replacing the slope length and gradient with upslope drainage area per unit of contour length (catchment area) and by introducing a transport capacity equation (Desmet and Govers, 1996; Van Oost et al., 2000; Mitsova et al., 1995; Mitsova et al., 1996; Mitso et al., 1998), which segments the long flow lines based on the concentration mechanism modeled by the catchment area and is simulating the deposition of the eroded material.

Beside rainfall-runoff, slope length and gradient, the others factors are important in the correct estimation of soil losses. Soil erodability refer to the difference in soil erosion, in the same environmental conditions, due to the properties of soils (Wischmeier and Smith, 1965). These properties are related to the way in which the soil resist to the erosional forces during the rainfall (dispersion, splashing and abrasion) and runoff (transporting forces). From a conceptual point of view, the soil erodability factor represent the soil removal per unit of applied external force (energy) in the conditions given by the unit plot (22.1 m in length, 9% in slope, 1.83 m in width and 1/250 ha in surface – Wischmeier and Smith, 1978; Renard et al., 1997). From a practical point of view the soil erodability factor express the average long-term soil response to erosion at rainstorms, by raindrop impact and sheet flow. Trough RUSLE2 implementation, also transport and deposition induced by local hillslope topography can be modelled (Renard et al., 1997).

Soil erodability factor (K) is computed by resolving the parameters of the equation (Wischmeier and Smith, 1978):

$$A_u = EI_{30} \times K, \quad (1)$$

when we consider L , S , C and P factors to have a value of 1 (the conditions of the standard unit plot, which is tilled and kept free of vegetation at least 2 years, to remove the effect of crop residues), and obtaining:

$$K = \frac{A_u}{EI_{30}}, \quad (2)$$

where A_u is the soil loss and EI_{30} values are yearly average values of rainfall-runoff erosivity of all storm in a particular area, giving a summation effect (E is the total storm energy and I_{30} is the maximum 30 minutes intensity). K values are also expressed as annual averages, but can be computed and RUSLE2 can be applied for a single day, month or season.

The soil loss (A_u) is measured for the unit plot for individual storms, with computed rainfall-runoff factor (EI_{30}), soil erodability factor (K) representing the susceptibility of soil to erosion, given a particular rainfall input. Fine textured soils with high clay content have low K value, 0.007-

0.020 $\frac{t \text{ ha } h}{MJ \text{ ha } mm}$ (NRCS USDA, 2000). Coarse textured soils (sandy soils) have also low K

values, of 0.007-0.026 $\frac{t \text{ ha } h}{MJ \text{ ha } mm}$ (NRCS USDA, 2000). Medium textured soils (silt loam soils)

have moderate K values of 0.033-0.059 $\frac{t \text{ ha } h}{MJ \text{ ha } mm}$, being moderately susceptible to soil erosion

(NRCS USDA, 2000). Silty soils have high K values over $0.059-0.086 \frac{t \text{ ha } h}{MJ \text{ ha } mm}$, being susceptible to erosion, also because of the crust formation (NRCS USDA, 2000).

Organic matter reduce soil erodability because it creates bind structure, reducing the effect of water flowing and increasing infiltration. Also the plant roots strengthen the soil cohesivity. Both effects are modelled in the cover management factor (C), rather than in soil erodability. Rock content at surface was shown also to influence soil erosion (Renard et al., 1997), by protecting the soil, but its impact was spread in a surface component, estimated in C factor, and a subsurface one which be estimated in K factor. The subsurface component is controlled by the permeability class, but because the effects are minor compared with the surface component, care must be taken when adjusting C factor.

It is also known (Renard et al., 1997) that K factor should be computed by different means than the classical way (there is need to compute K values spread across the year, and the time of K_{min} and K_{max}) for areas where there are significant differences between season given by soil freezing, wet and dry periods and cold and warm periods. Usually soil erodability is maximum during the spring, after tilling and just before the start of the growing season. In between, the soil erodability has a continuous trend toward minimum values at the final stage of the growing season. In the study area the growing season has 160 to 210 days in length (5.3 to 7 months), depending on altitude (Irimia et al., 2013), being inside the value range which do not require an approach different from the classic one (if the value tend toward 3.7 or 7.6 an approach different from the classic one needs to be taken, according to Renard et al., 1997).

2. MATERIALS AND METHODS

The nomograph of Wischmeier and Smith (1978) can be translated in the equation (Renard et al, 1997):

$$K = \frac{\left[2.1 \times 10^{-4} \times (12 - OM) \times M^{1.14} + 3.25 \times (s - 2) + 2.5 \times (p - 3) \right]}{100} \times 0.1317, \quad (3)$$

where OM is the organic matter percent, M is (percent of silt + percent of very fine sand)/(100-percent of clay), s is code for structure (1 is very fine granular, 2 is fine granular, 3 is medium or coarse granular and 4 is blocky, platy, or massive) and p code for profile permeability class (1 is rapid, 2 is moderate to rapid, 3 is moderate, 4 is slow to moderate, 5 is slow and 6 is very slow).

The 0.1317 value is used to convert from the K values in the US metric system to SI units, the value expressed in $\frac{ton \text{ acre } h}{100 \times acre \text{ ft} - ton \text{ in}}$ becoming expressed in $\frac{t \text{ ha } h}{MJ \text{ ha } mm}$ (Renard et al, 1997).

This equation is applicable only for the soils where silt fraction does not exceed 70%, and was derived from a database of 55 measured soil erodability values derived from rainfall-simulation experiments. The equation is well suited for less aggregated, medium textured surface soils of the American Midwest (Renard et al., 1997). Well-aggregated soils might introduce uncertainties when Eq. 3 is used (Römkens et al., 1986).

Römkens et al. (1986) gathered all the global of K measured data published in that time (225 surface soil horizons), both from natural and simulated observations, and containing rocks (diameter

>2 mm) less than 10% of the soil sample weight, and by considering the mean values of soil erodability of soils grouped into six textural classes and the mean geometric particle diameter for every class obtained the equation:

$$K = 0.0034 + 0.0405 \exp \left[-\frac{1}{2} \left(\frac{\log(D_g) + 1.659}{0.7101} \right)^2 \right], \quad (4)$$

$$\text{where } D_g [mm] = \exp \left(0.01 \times \sum_{i=1}^n f_i \log m_i \right) \text{ (Shirazi and Boersma, 1984)} \quad (5)$$

with $r^2 = 0.983$, D_g is the geometric mean particle diameter, f_i is the primary particle size fraction in percent, m_i is the arithmetic mean of the particle size limit of that size expressed in mm and n = the number of particle size fractions. With Eq. 4 the values of K are computed directly in $\frac{t \text{ ha h}}{MJ \text{ ha mm}}$.

This equation is shown to be the best method for the estimation of K values (Declercq and Poesen, 1992), because give good estimate values for all the soils, irrespective of the silt, clay and organic matter content or the aggregation status (Römken et al., 1988).

In the Romanian methodology for soil study (Florea et al., 2012) clay are aggregates with the diameter smaller than 0.002 mm, silt with the diameter of 0.002 – 0.02 mm and sand with 0.02 – 2 mm. The mean values for eq. 5 will be: for clay 0.001 mm, for silt 0.011 mm and for sand 1.01 mm.

In Romania, Moțoc et al., 1973, Moțoc et al., 1975 and Moțoc et al., 1979 provided values for K factor (table 1) without specifying exactly how they estimated the values. They also use a variant of USLE without specifying the source, and modify the implementation, considering soil erodability and the other factors besides rainfall-runoff erosivity as a correction coefficients. The most important aspect to be noted is that they do not specify if the values are computed after USLE (which was published at that time) methodology or are simply transformed values in SI units, from cited values in the USLE methodology. We believe that these coefficients are computed as a correction coefficient considering values from the Romanian soil erosion plots, only rainfall erosivity being computed after USLE methodology (Moțoc et al., 1973).

For the study area (54670 ha) we used a database of 530 soil profiles and 4539 soil units (with surfaces ranging from 10 to 7 000 000 m²). Only 512 soil units had sampled profiles, in this case the soil granulometry being taken from the soil profile sampled in that soil unit. From these, 18 soil units had sampled two soil profiles per soil unit. For the soil units without sampled soil profiles, the closest similar soil profile was used to add the soil granulometry. Where complex soils were encountered, multiple neighbor soil profiles (according to the soil type) were chosen and depending on the proportion of every soil type in the complex, soil granulometry was derived as a weighted average of all the soil profiles from that complex.

Both Eq. 3 and 4 were used to estimate K values. The first horizon granulometry was used. A further way to increase the resolution is to take into consideration the soil erosion class. The soil erosion class specify which horizons are eroded. For the soils from the study area these are the classes (Moțoc et al., 1973):

- Unappreciated erosion: the soil profile has the same features as the soils from plateaus;
- Moderate erosion: up to 50% of the A horizon is eroded;

- Strong erosion: 50 to 100% of the A horizon is eroded and up to 100% from A/B horizon;
- Very strong erosion: B and C horizons are partially or total eroded.

Table 1. The soil erodability coefficient values proposed by Moțoc et al., 1973

No.	Description*	K value
1	eroded soils, with weak cohesivity; fine textured luvisols, prepodzols, phaeozems, rendzic leptosols	1.2
2	eroded soils, with weak cohesivity; medium or heavy textured phaeozems, rendzic leptosols	1
3	medium eroded soils; medium textured luvisols, prepodzols, phaeozems, rendzic leptosols	0.9
4	medium eroded soils, with strong cohesivity; fine textured luvisols, prepodzols, phaeozems, rendzic leptosols	0.8
5	medium eroded soils, with medium cohesivity; silty-sandy textured phaeozems	0.7
6	weakly/moderate eroded with medium cohesivity; silty-sandy textured chernozems	0.7
7	weakly/moderate eroded deep soils with strong cohesivity, well developed structure chernozems, phaeozems	0.6

*soils are described with the equivalent from WRB, after the SRTS 2012 (Florea et al., 2012)

Based on the erosion class (where it was available in the soil formula) the granulometry was taken from other horizons than the first horizon. For ravines, the closest profile C horizon granulometry was considered.

Channels and lakes were attributed with K values of 0 because soil erosion in these areas is not a characteristic phenomenon. Built areas have received the values of the closest soil profile, considering that soils are present in these areas, and the erosional impact is given by the cover factor. If the cover is a building, the area will be eliminated from the analysis (by setting cover factor to 0). If the cover is agricultural field, orchard or vineyard, the crop factor value will be given by that land use. This method under estimate the erosional impact of construction sites, but since these features have a non-predictable frequency of presence, only targeted studies toward this phenomenon are possible. For forest soils the same method like for built areas was applied.

For Eq. 3, beside granulometry other parameters needed estimation. For the *M* parameter, the soil profiles require the use of very fine sand proportion values, which are expressed in US values (very fine sand has particles with diameter between 0.05 and 0.1 mm). In the Romanian system (Canarache et al., 1987) the fine sand fraction contains the particles with diameters of 0.02 to 0.2 mm, while the silt fraction the particles with diameters of 0.002 to 0.02 mm. Comparing these values with the US system, the fine sand in the Romanian system contains a part of silt, very fine sand and a part of fine sand texture classes. This situation required a transformation of the Romanian system particle size system into the US particle size system, with the help of log-linear transformation implemented in the *soiltexture* R package (<https://cran.r-project.org/web/packages/soiltexture/index.html>).

For the *s* code, the texture indicator (Indicator 23A according to Canarache et al. (1987) and the soil type were used. Chernozems, Phaeozems and Fluvisols with mollic A horizon have for the *s*

code a value of 1. Regosols and eroded soils have for the *s* code a value of 3. The other soil types and complexes dominated by Regosols and eroded soils have for the *s* code a value of 2. The *s* code 4 was used, only for the hillslopes and ridges from the extreme western part of the study area, because here soils with rock fragments at surface might appear.

For the *p* code the total porosity can be computed from granulometry values (Niculiță, 2012), and according to Canarache et al., 1987 (indicator 50) can be classified in six classes: very high, high, medium, small, very small, extremely small, which have the corresponding values in USLE *p* codes.

For the validation of *K* values, soil losses and sediment yields were obtained using WaTEM/SEDEM 2006 (Van Oost et al., 2000; Van Rompaey et al., 2001; Verstraeten et al., 2002). This model use RUSLE2 and routes the sediments trough channels and ponds, estimating soil losses and sediment yields. RUSLE2 factors were estimated as follows:

- rainfall-runoff factor was taken from Panagos et al. (2015) data;
- LS values were computed using WaTEM/SEDEM 2006 implementation on a high resolution DEM, resampled at 20 m;
- C factor values were assigned after Doru and Niculiță (2015) assessment;
- P factor values were assigned according to the RUSLE2 methodology (Renard et al., 1997) to support practice extracted from the high resolution DEM and high resolution aerial images.

3. RESULTS AND DISCUSSIONS

The granulometry of the soil profiles (fig. 1) are mainly spread in the medium textures on the texture triangle (Romanian system), medium clayey silt having the biggest number of soil profiles, followed by medium silt and silty clay. A few soil profiles go into the sandy silt class, medium clay, dusty clay, clayey and dusty silt. Chernozems, Phaeozems and Fluvisols have the most variate spread of granulometry values. Luvisols are mainly spread in the medium clayey silt and medium silt classes.

The mean value of soil erodability factor in Bahluiet catchment is 0.0157. The *K* values spread between 0.01 and 0.03, with a distribution shape with left asymmetry (fig. 2). The highest frequency of values is spread in the 0.01 to 0.022 range. The highest frequencies are around 0.02 value. Again, Fluvisols, Chernozems and Phaeozems have the biggest spread of *K* values (fig. 3). Luvisols have a spread of *K* values between 0.01 and 0.022.

Spatially, the biggest *K* values have the floodplain Fluvisols (fig. 4), with values bigger than 0.025. On hillslopes the values are between 0.01 and 0.025. The soils from the central, south and east part of the catchment have the biggest *K* values, while in the western and northern part have the lowest *K* values. This spatial pattern we believe to be associated with the geologic deposits of the study area, the higher values being associated with the presence of clay, loess and loamy deposits, while the lower vales from the west part to the presence of sands.

The values presented above refer to the *K* estimates computed with Eq. 4. The values computed with Eq. 3 (fig. 5) have values which are incomprehensibly high for the soil of the study area (the minimum is 0. and the maximum is 0.77, with the majority of the data between 0.15 and 0.5). We believe that this is related to the fact that Eq. 3 is mainly made for US soils, and the used coefficients can increase artificially the values. The mean value obtained with Eq. 3 is 0.032.

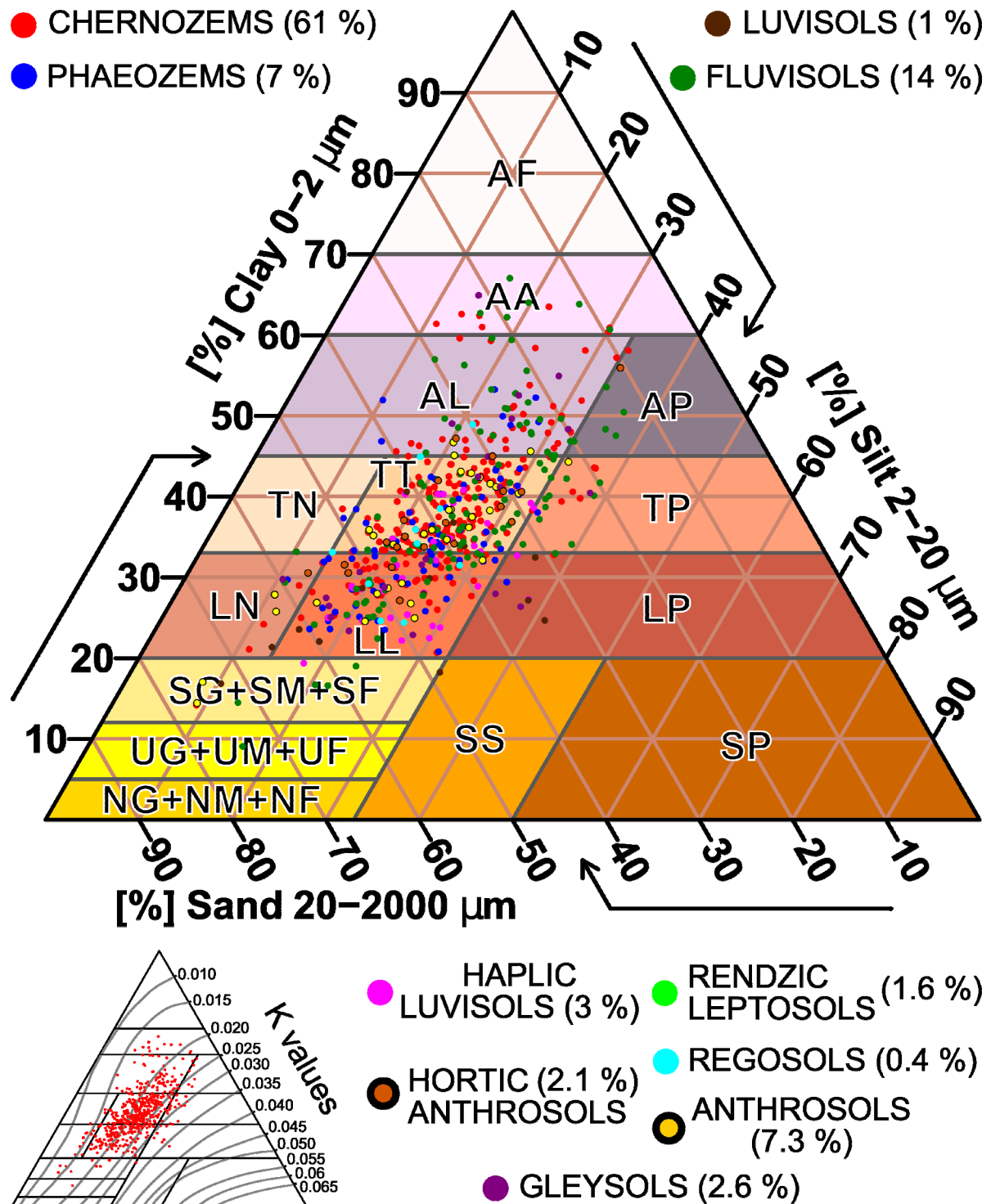


Figure 1. The granulometry of the 530 soil profiles from Bahluieț catchment (according to Romanian Soil Texture Classification – Florea et al., 2012).

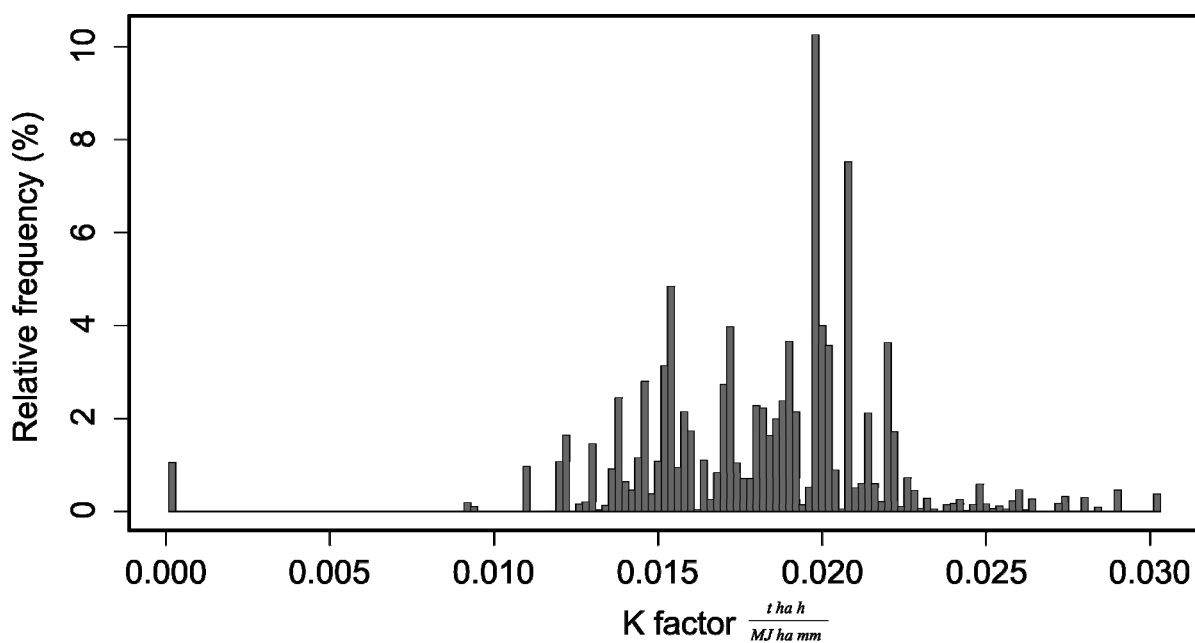


Figure 2. The distribution of RUSLE2 K factor values in Bahluiet catchment.

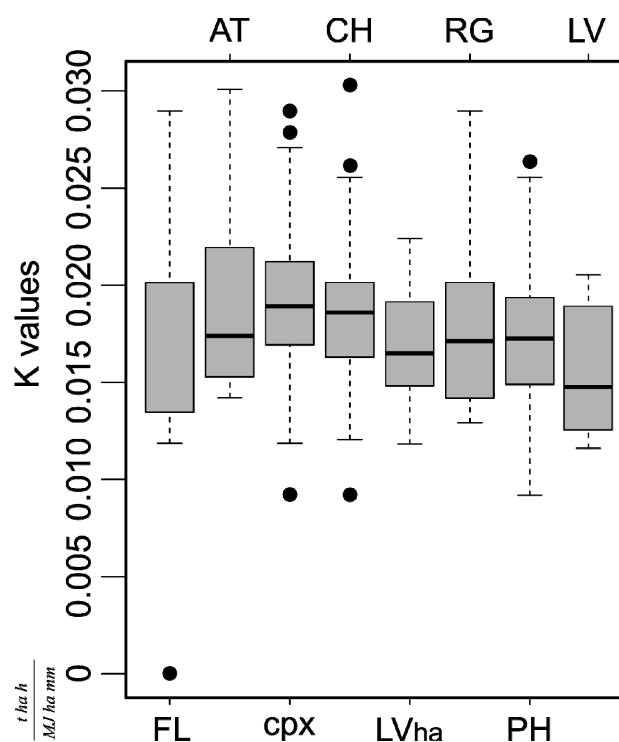


Figure 3. The boxplot of RUSLE2 K factor values in Bahluiet catchment for different soil types.

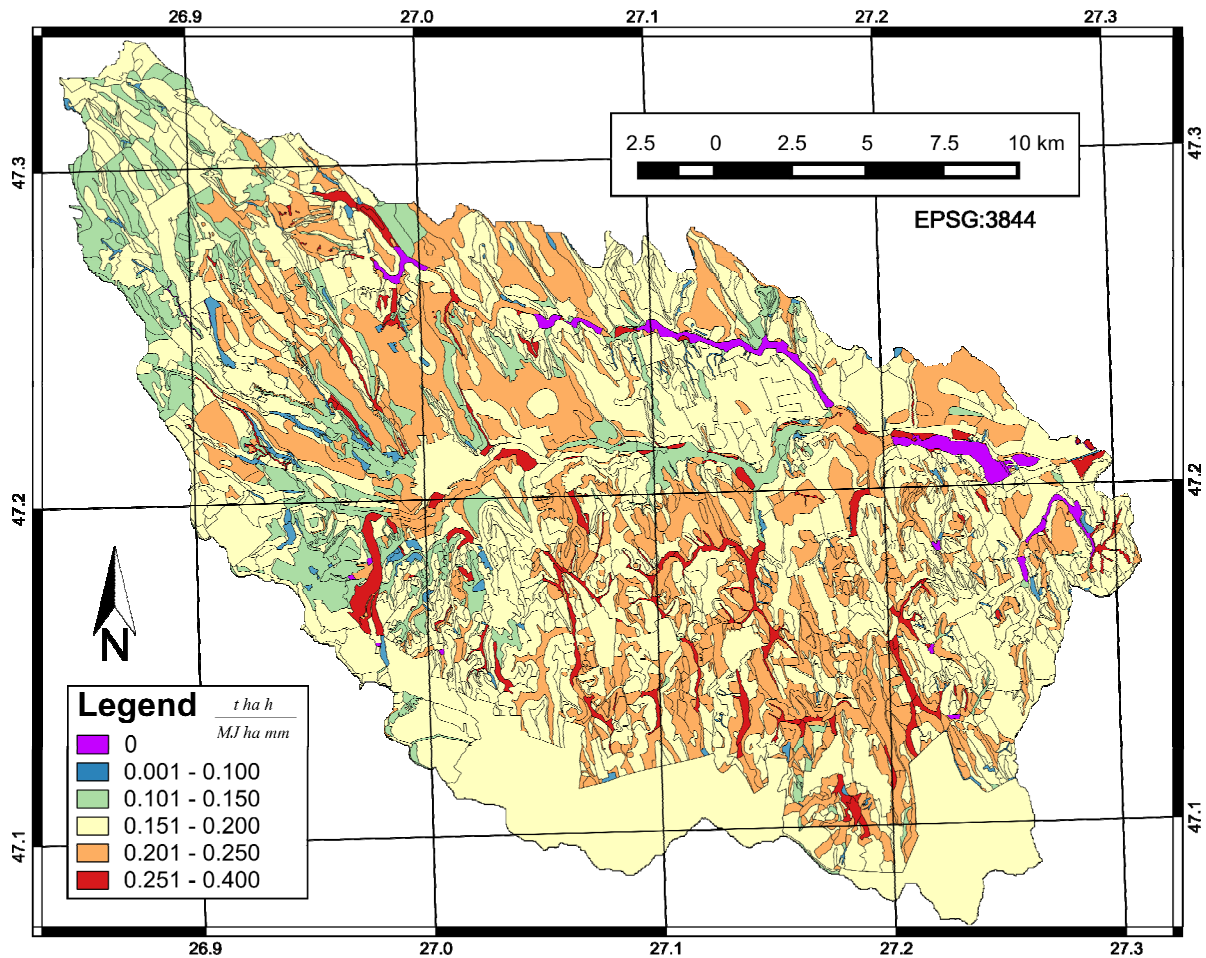


Figure 4. The RUSLE2 *K* factor values for the soils units in Bahluiet catchment, computed with Eq. 4.

With this value, soil losses are higher than those reported by Bucur et al. (2011), with 2 to 20 t/ha/y for crops. Sediment yields from these soil losses can go up to 8.8 t/ha/y, which is far beyond the values given by the literature for the study area (Rădoane and Rădoane, 2005). We compared our data also with the Panagos et al. (2014) *K* dataset for 28 EU countries (fig. 6), which also used the Eq. 3. The mean value for Bahluiet catchment for this datasets is 0.043 which again we consider that is overestimated, the values ranging between 0.026 and 0.054. The soil losses for these values are double in size compared with the data of Bucur et al. (2011), with for 3 to 30 t/ha/y for crops. The sediment yield is 11.6 t/ha/y. The values obtained through the use of Eq. 4, for *K* factor, soil loss (0.1 to 1.5 t/ha/y for crops) and sediment yield (2.17 t/ha/y) are also consistent with the texture of soils from the legacy database, Bucur et al. (2011) and Rădoane and Rădoane (2005) values. Beside the overestimation, the values obtained using Eq. 3 and the values of Panagos et al. (2014), does not follow the spatial trend given by the lithology.

4. CONCLUSIONS

In the present approach we have estimated soil erodability factor (*K*) values for the RUSLE2 model, based on the soil granulometry from a soil legacy database, with the methodology proposed

by RUSLE2 manual. The correct estimation of all RUSLE factors is an important step in obtaining soil loss estimates which are close to the real situation. We can also remark that from the RUSLE2 methodology, the equation proposed by Römken et al. (1986) is consistent with the reality from our study area (as also Declercq and Poesen, 1992 state for Belgium). This equation is not so prone to errors because of the straightforward computation of K factor from granulometry values, without the need to transform the Romanian particle size classes in the US system and to consider structure and permeability codes.

We have also proposed an approach to increase the spatial variability of K values, by using the erosion degree, as it is present in the soil legacy database, to choose a different horizon of soil, instead of the A horizon, where erosion is present, according to its depth, given by the erosion degree class.

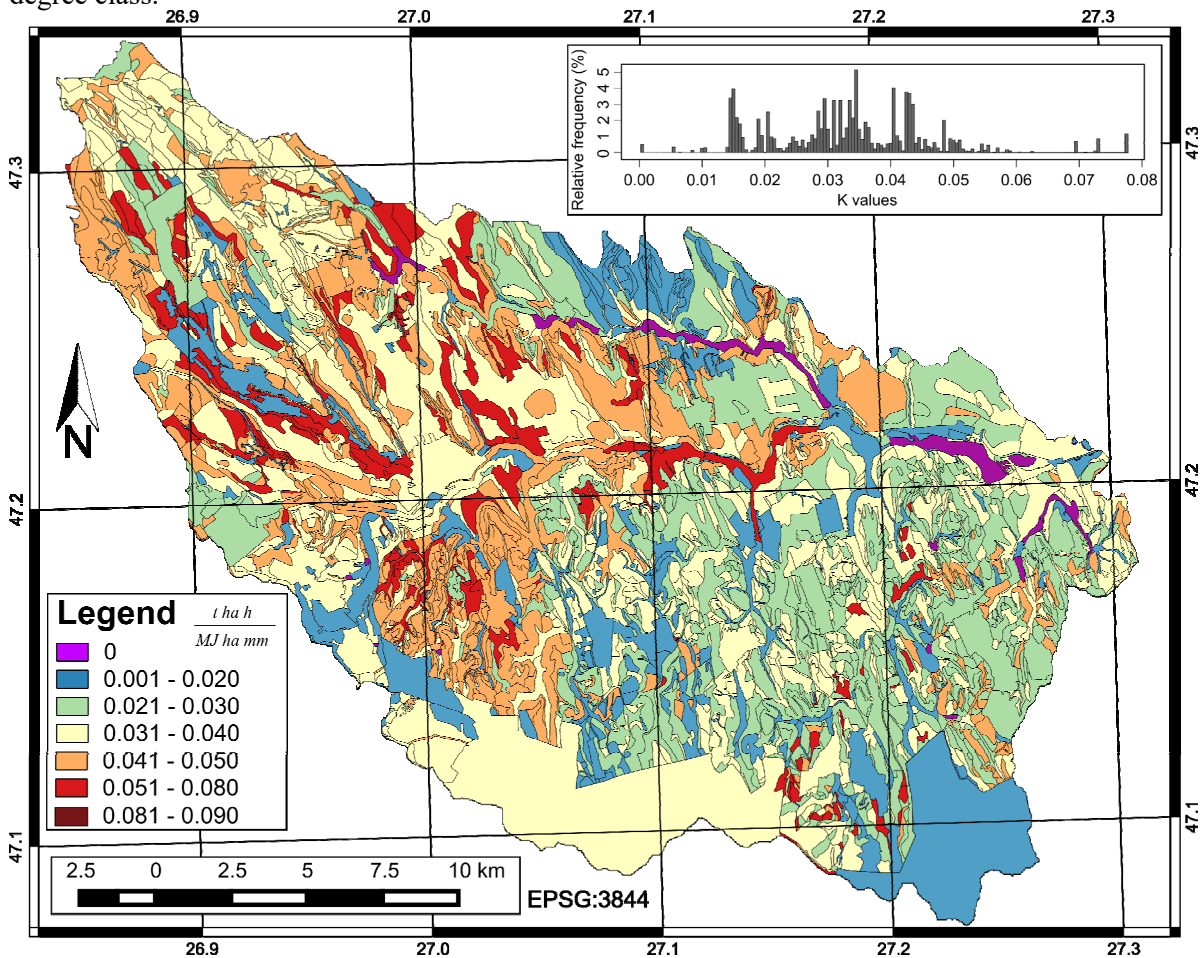


Figure 5. The RUSLE2 K factor values for the soils units in Bahluiet catchment, computed with Eq. 3.

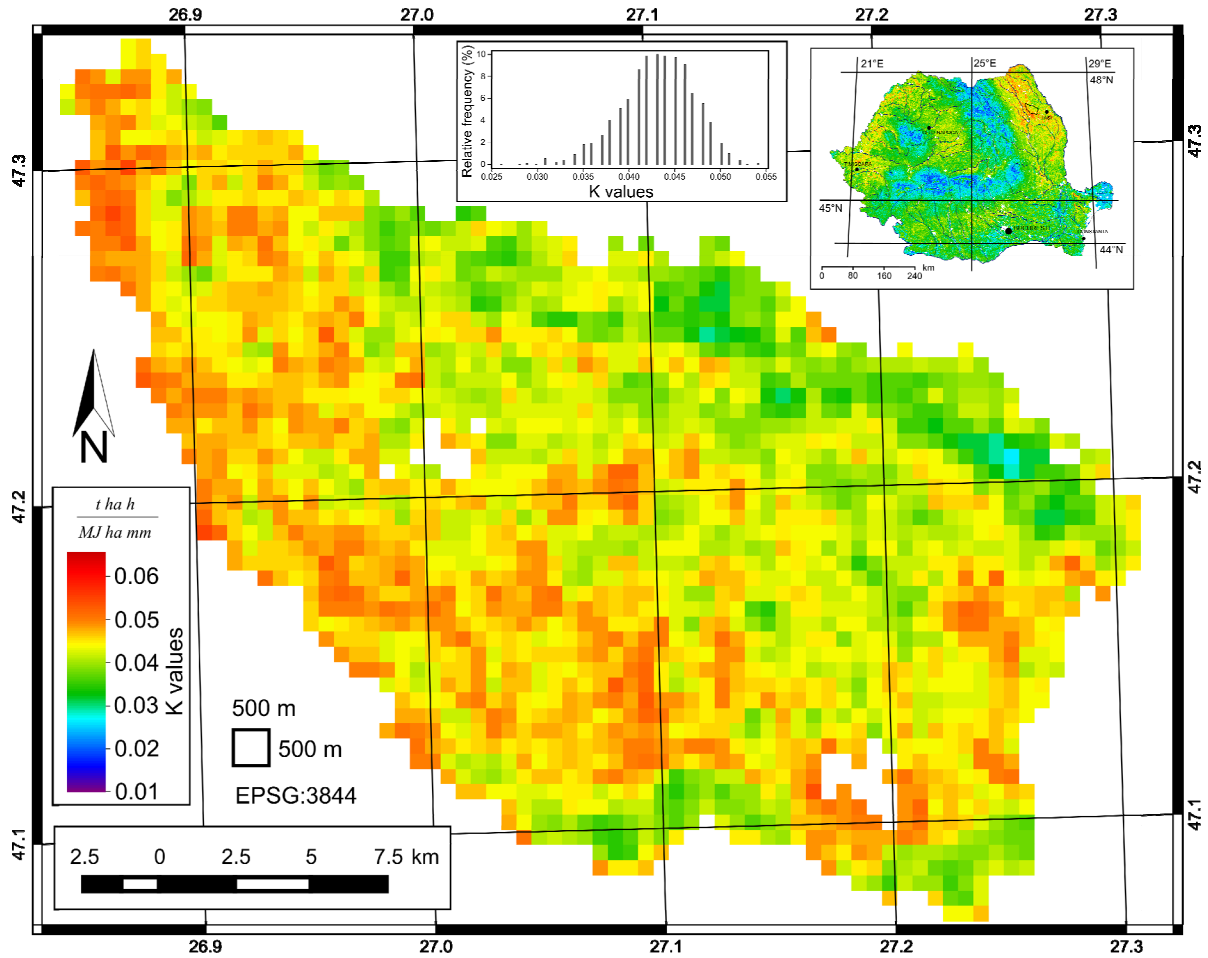


Figure 6. The RUSLE2 *K* factor values for Bahluieț catchment obtained by Panagos et al. (2014).

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